TEST REPORT

IMPROVEMENTS TO A SMOKE GENERATOR FOR USE IN WIND TUNNELS

by

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SUMMARY

In order to overcome disadvantages in existing methods, a new smoke-system for wind tunnels has been investigated. The system consists simply of a device for mixing jets of anhydrous ammonia and sulphur dioxide gases. It is instantly controllable, produces dense white smoke without clogging, is easily portable, and poses no fire risk. Provided simple precautions are taken there is no danger of toxic concentrations building up, and the substances used are non-corrosive, readily available, and cheap. The system has been improved by the design of a large-capacity probe for use in high-speed airstreams.

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1.0 INTRODUCTION

The origin, design, and use of a simple smoke generator are described in Reference 1. This generator has been used extensively in many laboratories, at airspeeds of up to 60 ft/sec (18.3 m/sec). The requirement arose to visualize airflow at higher speeds. The present report describes a probe which has been used in airstreams at speeds up to 125 ft/sec (38.1 m/sec), and could easily be run at far higher airspeeds.

2.0 APPARATUS

Jets of anhydrous ammonia and sulphur dioxide gas are emitted from a probe, and mix in free air just beyond the probe tip. This produces a dense white cloud of ammonium sulphite "smoke" in the presence of atmospheric moisture The apparatus is instantly controllable by turning on or off the gas supply to the probes.

The apparatus is extremely simple and flexible. The gases are supplied in liquid form in standard cylinders in a range of sizes, fitted with shut-off valves. Standard needle valves are available from gas suppliers, with delivery fittings suitable for copper tube.

The cylinder and valve assemblies are clamped into racks, and 1/4 inch (6.35 mm) (or other suitable size) copper tubes led to the nozzle. If a flexible lead is required, a length of Tygon tubing is used to connect the metal lines to the nozzle.

The probe itself can be of a variety of designs. The essential requirement is that the jets of the two gases meet and are thoroughly mixed in free air. The pipes, therefore, conduct only pure gas, which cannot cause any blockage, and the smoke is formed in the free air just beyond the tip of the probe. The design of the small low-speed probe described in Reference 1 is shown in Figure 1. It directs the two jets at 90 degrees to each other, to meet at a point about 1/16 inch (1.6 mm) beyond the tips of the tubes. This results in effective mixing as shown in Figure 2, and does not build up a residue in the probe, except at very high flows.

A new probe has been designed, and has performed well at up to 125 ft/sec (38.1 m/sec), where it produced a good plume for some 20 feet (6 metres) or so. Its quality over the first 10 feet (3 metres) is illustrated in Figure 3. A short film (Reference 3), also shows the probe being used to visualize air flow around a VTOL Fan-in-Wing test model.

The new probe is shown in Figure 4. At the higher speeds at which this probe operates, effective mixing takes place without inclining the jets towards each other. This probe shows no sign of building up a blob of residue, even at high gas flows. Figure 5 shows that the smoke forms about one diameter downstream from the nozzles.

If much higher airspeeds are encountered, it should be effective to add a further pair of tubes, to make a six-nozzle array of parallel jets, with alternate tubes carrying ammonia and sulphur dioxide. For effective mixing this is preferable to using fewer and larger tubes.

If the operator cannot see the smoke plume from the control valve position, two mercury manometers can be "teed" into the gas lines after the valves, as shown in Figure 6. The ammonia is turned on, and then the sulphur dioxide flow is adjusted to get the densest smoke. The two manometer readings are then noted. If this is done for a range of settings, the valves can then be reset at any time without having to observe the smoke plume each time, provided that the same pipes, with the same pressure loss, are always used. In a typical case, where about 20 feet (6 meters) of 1/8 inch (3.2 mm) diameter plastic tubing connected the valves to the probe, in a high-speed airstream, the manometers were set at 7 inches (178 mm) Hg. for ammonia, and 14 inches (356 mm) Hg. for sulphur dioxide.

3.0 OPERATION

As a safeguard to anyone using the apparatus, the "Precautions for Use" section is here reprinted from the earlier report.

It may be added that in six years of continual use no damage has occurred although one minor accident has been experienced with the apparatus. In this case an operator with an alergic condition suffered an acute attack of laryngitis, which emphasized the importance of good ventilation during use.

4.0 PRECAUTIONS

Provided the generator is used carefully in an adequately ventilated area, it is perfectly safe. The precautions for handling cylinders of liquid gas are well known, and are available in pamphlet or poster form from the gas suppliers.

A standard work (Reference 2) states that the maximum acceptable continuous working concentrations of ammonia and sulphur dioxide are 100 parts per million parts of air, and 5 parts per million of air, respectively. In both cases, far lower concentrations are immediately detected by smell and taste, and conditions anywhere near the acceptable limit produce warning irritation of the eyes, nose and throat. It is stated that "in industry, cases of severe exposure are rare, because the gas is so irritating that it provides its own warning of toxic conditions" and this warning does not wear off with exposure. The First Aid for moderate exposure is to remove the subject to fresh air, to wash out the eyes with warm water, and to give plenty of water to drink.

In case a valve or pipelines should be damaged, it is strongly advisable to have an ammonia respirator within easy reach of the operator while tests are in progress, since a momentary strong dose of the gases would temporarily choke him and fill his eyes with tears, so that escape to clear air would be made difficult. It is important to note that, while sulphur dioxide is itself non-corrosive, it will dissolve in water to form sulphurous acid, which is corrosive. Surplus sulphur dioxide, not neutralised by the ammonia, or sulphur dioxide escaping from a leaking valve, could therefore combine with the water in damp air and form enough sulphurous acid to corrode metal models or wind tunnel machinery, compressors, etc. It seems advisable to remove the gas lines from the tunnel and run with plain air to remove all traces of sulphur dioxide from the tunnel after smoke tests.

Once the gases have combined to form smoke, the ammonium sulphite so formed is a harmless white powder. It is very soluble in cold water, so that if a wind tunnel model becomes coated it may be wiped clean with a damp cloth.

5.0 REFERENCES

1. Fowler, H.S.	A Smoke Generator for Use in Wind Tunnels. NRC, DME Test Report MET-452, National Research Council of Canada, August 1964.
2. Sax, N.I. et al	Dangerous Properties of Industrial Materials. 2nd Ed., Reinhold Publishing Company, New York, 1963.
3. Bassett, R.W.	Fan-in-Wing Crossflow Studies. NRC, DME Film Serial No. 22, National Research Council of Canada, 1970.

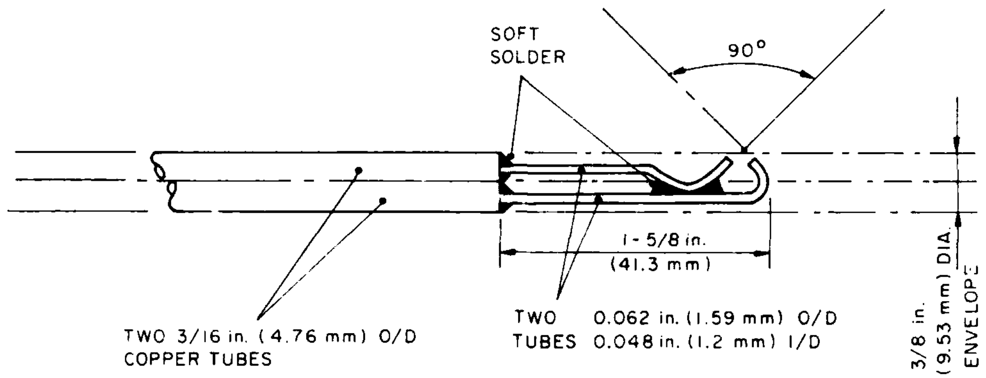


FIG. 1 : CONSTRUCTION OF SMALL LOW SPEED PROBE HEAD

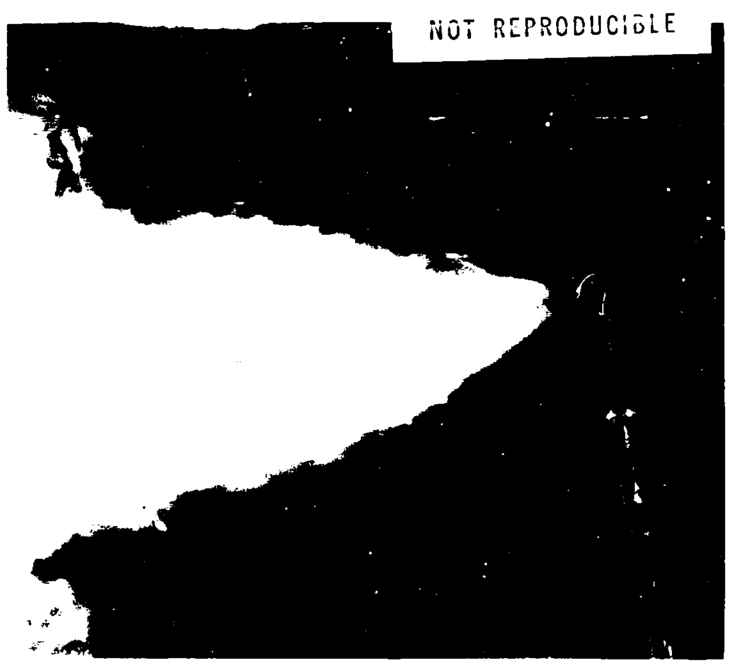


FIG. 2 : CLOSE-UP OF PROBE SHOWING
GASES MIXING TO FORM SMOKE

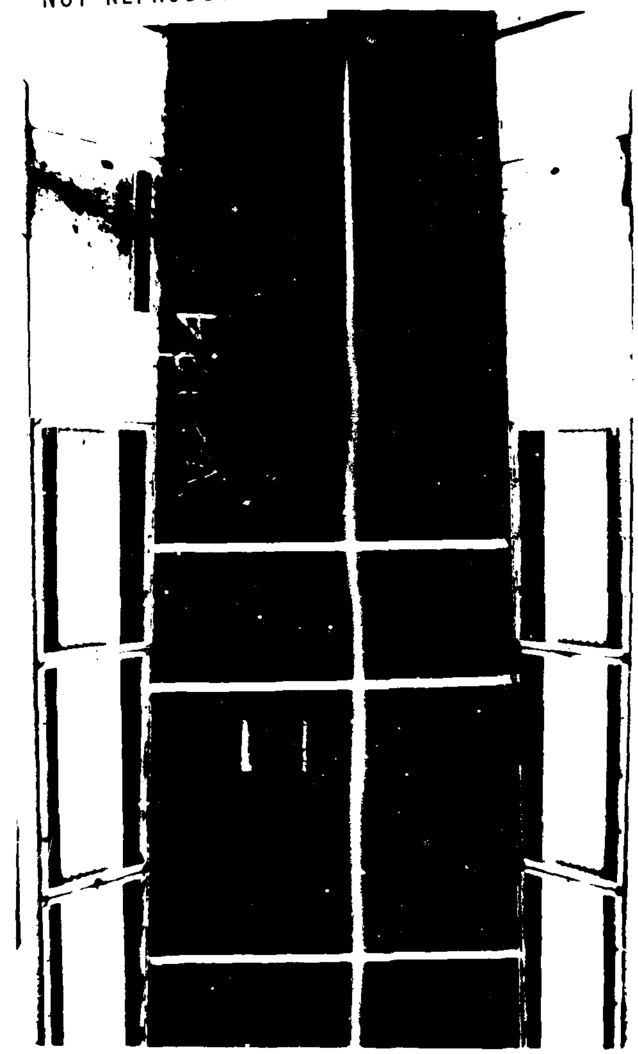
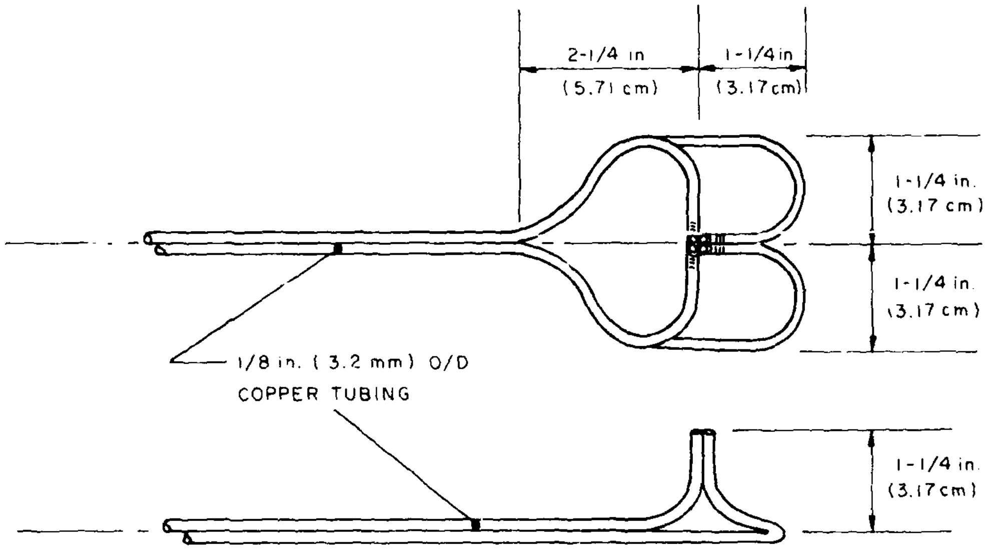


FIG. 3 : NEW PROBE, SHOWING PERFORMANCE IN AN AIRSTREAM MOVING AT 124 ft/sec (37.8 m/sec)



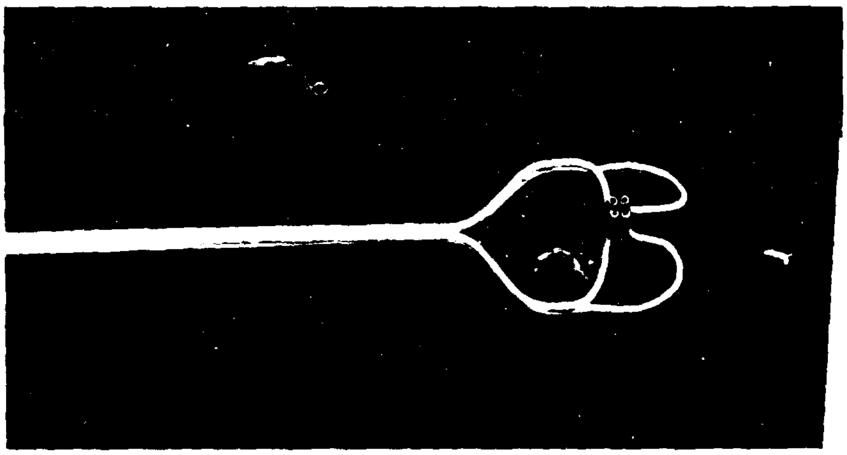


FIG. 4 : CONSTRUCTION OF LARGER HIGH SPEED PROBE HEAD

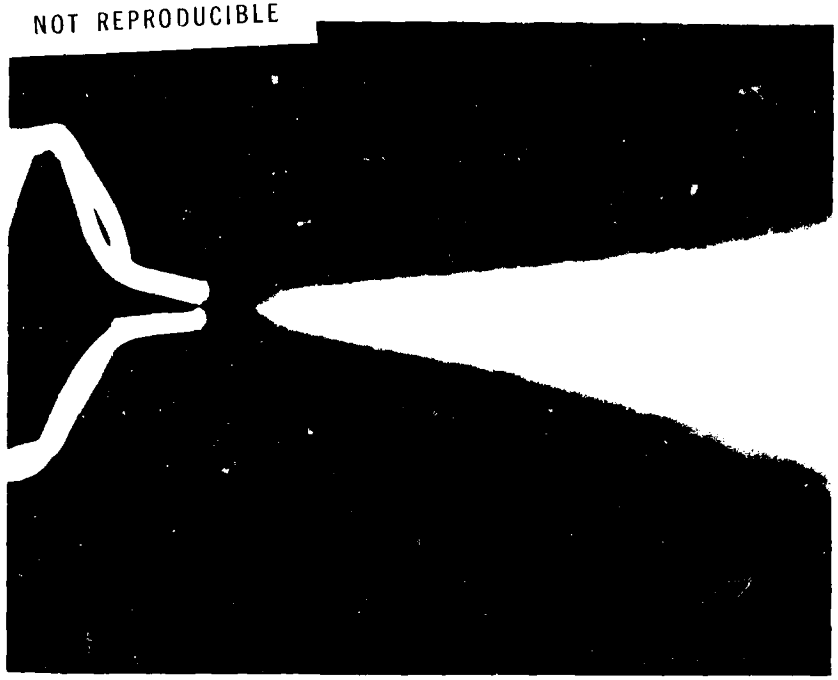


FIG. 5 : DETAIL VIEW OF NEW HIGH SPEED PROBE HEAD, ILLUSTRATES MIXING OF GASES AWAY FROM NOZZLE

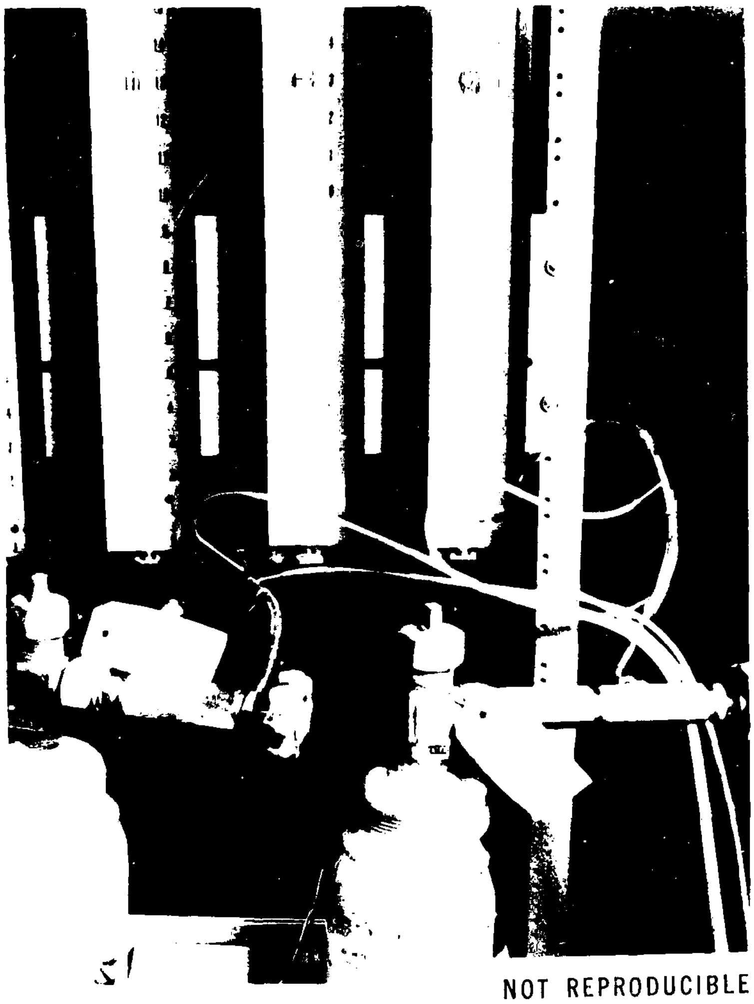


FIG. 6 : MERCURY MANOMETERS USED TO CONTROL SMOKE NOZZLE REMOTELY